Laboratoire de Mécanique des Solides
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Symposium Jean Mandel

From theoretical to experimental mechanics

Friday, June 14th, 2024

Poisson Amphitheatre
École polytechnique

Contact : laurent.guin@polytechnique.edu

Plenary Lecture

by Hussein Nassar

How periodic surfaces bend

Compliant shell mechanisms are creased and corrugated thin-walled structures that can drastically change shape to move, deploy, or adapt to a changing environment. They have found use cases in the context of recent space programs and in other domains ranging from biomedical technology to architecture. Not unlike slender beams, thin shells prefer bending over stretching. Ideally, thin shells deform isometrically should isometric deformations exist. The problem of finding, or disproving the existence of, isometric deformations for various surfaces preoccupied many mathematicians and mechanicians. The most noteworthy results undoubtedly pertain to three broad categories of surfaces: developable surfaces, convex surfaces, and axisymmetric surfaces. In the modern context of computer graphics, discrete differential geometry and "Origami science," more focus has been directed towards tri- and quad-based polyhedral surfaces.

In this lecture, we report on recent results that characterize the isometric deformations of periodic surfaces, i.e., surfaces that are invariant by a two-dimensional lattice of translations. Inspired by the theory of homogenization, two classes of effective isometric deformations are introduced, membrane modes and bending modes, identified by whether their long-range behavior is membrane-like or bending-like. The main theorem proves an orthogonality relationship between the two classes. Thus, if a surface gains a membrane mode, it loses a bending mode, and conversely, in such a way that the total number of modes, membrane and bending combined, can never exceed 3. The main assumption of the theorem is that the periodic surface is simply connected (i.e., without holes). Beyond that, the theorem invariably handles piecewise smooth surfaces including smooth, polyhedral and "curved-crease" surfaces. This universality is anchored in the proof technique that is free of specific constructs (e.g., linkages, torsal rulings, conjugate nets) and instead uses high-level arguments (e.g., symmetry and integral theorems). The theorem succeeds in qualitatively describing how various periodic surfaces bend into domes or saddles and finite element simulations of thin elastic shells validate the quantitative findings in the limit of vanishing thickness. The work hopefully sheds new light on how thin corrugated shells behave be it in modern morphing applications or in classical structural ones and, just as hopefully, brings closer the communities of origamists, geometers, and mechanicians.

Hussein Nassar

Assistant Professor
Department of Mechanical and Aerospace Engineering
University of Missouri – Columbia

Hussein Nassar is an Assistant Professor of Mechanical and Aerospace Engineering at the University of Missouri – Columbia (MU). He attended École des Mines de Paris until 2012 while pursuing a parallel degree in Mathematics awarded by Université Paris VI in 2011. He graduated with a PhD in Mechanics from Université Paris-Est Marne-la-Vallée in 2015 and joined the faculty at MU in 2018.

The work of H. Nassar investigates theoretical models of continuum mechanics applicable to architected solids and shells with emphasis on interactions between geometry and elasticity, both in static and dynamic regimes. His research has been supported by the U.S. National Science Foundation and the U.S. Army Research Office; he is a current recipient of the NSF CAREER Award.

Friday, June 14th, 2024 Program

Poisson Amphitheater

08:30 - 08:55 am	*Registration and Welcome Coffee*
08:55 - 09:00 am	**Welcome Address** by **Andrei Constantinescu**, LMS director
09:00 - 10:00 am	**Plenary Lecture** by **Hussein Nassar** *How periodic surfaces bend*
10:00 - 10:20 am	*Coffee Break*
10:20 - 10:45 am	**Florian Gouhier** *A comparison of finite strain viscoelastic models based on multiplicative decompositions*
10:45 - 11:10 am	**Thomas Merlette** *Application of the FFT-based homogenization method to estimate anisotropic linear viscoelastic properties of unidirectional fiber-polymer composites*
11:10 - 11:25 am	**Quentin Dollé** *From thermal activity in DED process to microstructure prediction*
11:25 - 11:50 pm	**Viviane Bruere** *Crushing behavior of microarchitected materials*
12:00 - 13:45 pm	*Lunch in Jean Mandel room*
13:45 - 14:10 pm	**Nina Du** *Micromechanical study of synthetic rock salt by X-ray µCT in situ triaxial tests*
14:10- 14:35 pm	**Matthieu Lusseyran** *Multi-scale experimental deformation and damage initiation of clay-rich rocks*
14:35 - 15:00 pm	**Qian Wu** *Exploration of the mechanical role of stromal stria*
15:00 - 15:20 pm	*Coffee Break*
15:20 - 15:45 pm	**Zehui Lin** *Fabrication and characterization of soft magnetorheological foams*
15:45 - 16:10 pm	**Xavier Bruant** *Effect of stress on the electrochemical response of amorphous silicon electrodes*
16:10 - 16:35 pm	**Camilla Zolesi** *Stability and crack nucleation in variational phase-field models of fracture: effects of length-scales and stress multi-axiality*

Jean Mandel

Founder of the Laboratoire de Mécanique des Solides

After brilliant secondary studies, Jean Mandel went on to École Polytechnique in 1927 and later to École des Mines. In 1932 he became a professor at École des Mines de Saint-Étienne and in 1948 at École des Mines de Paris. From 1951 to 1973 he was professor of mechanics at École Polytechnique.

Jean Mandel's research career was devoted mainly to the mechanics of solids and the strength of materials. In 1961 he created the Laboratoire de Mécanique des Solides, a laboratory common to École Polytechnique, École des Mines de Paris, École des Ponts et Chaussées and associated to the Centre National de la Recherche Scientifique. In October 1964 he founded and became the first president of the Groupe Français de Rhéologie. In 1980 he became "honorary member" of this group.

The scientific work of Jean Mandel covers a very wide field with a bibliography listing more than 150 articles and 5 books. He presented original ideas on the buckling of beams and shells, the finite deformations of solids, laminar flow in porous media, the bearing capacity of shallow foundations, the punch resistance of a two-layer medium, the stability of underground cavities, the plastic flow of metals, and the effect of cyclic loading on structures, as well as contributions to the fields of thermodynamics, rolling friction and homogenization.

But Jean Mandel's influence extended far beyond the field of his personal research. A good many students were trained, under his direction, in the Laboratoire de Mécanique des Solides. A fine teacher and a constant stimulus to his research group, he gave his time generously to study the details of manuscripts that were sent to him and to suggest the minor modifications he deemed necessary. Those who had the privilege of working with him were left with an impression of palpable scientific passion and moral rigor that will continue to be an example for generations to come.

Jean Mandel passed away on the 19th of July 1982, the victim of a tragic accident at the very height of his intellectual prime.

Text by Pierre Habib

The Jean Mandel Symposium is open to all students, researchers and scientists interested in the proposed topic. It combines, in an informal setting, a keynote presentation by an internationally renowned scientist and talks given by young researchers associated with the laboratory.